CCXXII.—*Influence of Poles and Polar Linkings on Tautomerism in the Simple Three-carbon System. Part II. Prototropy in Bis-quaternary αγ-Propenylenediammonium Salts.*

By CHRISTOPHER KELK INGOLD and EUGENE ROTHSTEIN.

IN Part I (J., 1929, 8) the first evidence was advanced that the three-carbon system can exhibit prototropy without the occurrence of co-valency changes beyond the limits of the system itself; or, expressing the matter in terms of the ionic-electromeric mechanism, which may now fairly be claimed as established, the evidence given was that the simple three-carbon system * could itself hold the anionic charge necessary for mobility. The example, however, was not a simple one, the phenomenon of chief interest being overlaid by others, and, in point of fact, the instance was fortuitously encountered during an attempt to produce an elementary three-carbon system of the form

$$\{R^1R^2R^3\overset{\oplus}{N}\cdot CH_2\cdot CH{:}CH\cdot\overset{\oplus}{N}R^4R^5R^6\}$$

Here there is no unsaturation of any kind (*e.g.*, multiple linkings, potential double linkings as in aryl groups, atoms with unshared electrons or expansible octets) beyond the limits of the $^-CH_2\cdot CH{:}CH^-$ group itself. This system has been discussed on several occasions since 1926 (see Part I; also Burton and Ingold, J., 1928, 904), and it has been anticipated from theoretical considerations that it would be mobile, although less strongly so than analogous carbonyl-containing systems of the type of the glutaconic esters; but only quite recently have we been able to realise the elementary system formulated and test these expectations.

Our experiments on the formation of this system included the exploration of three possible routes (in addition to that which led to the results recorded in Part I) characterised respectively by intermediate salts derived from (*a*) β-chlorotrimethylenediamine, (*b*) β-hydroxytrimethylenediamine, (*c*) β-methoxytrimethylenediamine. Only route (*a*) led to the desired structures, but the others, (*b*) and (*c*), were carefully examined for reasons additional to the purely synthetical objective. For we expected the unsaturated salts to be mobile in the presence of hydroxide and alkoxide ions, and, had these salts been capable of production by dehydration of β-hydroxytrimethylenediammonium salts, for instance (route *b*), the question would at once have arisen whether the isomeric change was prototropic at all, or whether, on the contrary, it proceeded by prior hydration of the double linking. Since the case of the di*iso*butylenes comes naturally to mind in this connexion, it may be remarked that, whilst hydroxide ions cannot cause hydration of an olefinic linking in the absence of an attached electron-sink (only hydrions, or their equivalent, can do that), alkaline hydration of the system $\overset{\beta}{C}\overset{\curvearrowright}{=}C\rightarrow\overset{+}{N}$ is theoretically possible on account of the β-reactivity towards basic reagents expected to be induced by the electron-attraction of the positive pole. A similar argument applies to route (*c*): had the unsaturated salts been capable of production from β-methoxytri-

---

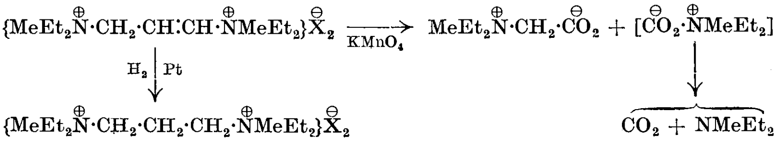
* As here used, the phrase connotes a system in which unsaturation ceases beyond the limits of the group $-CH\cdot C{:}C-$. We do not regard the interconversion of the di*iso*butylenes as prototropic, because the conditions of catalysis show that this reaction is initiated by addition to the double linking.

methylenediammonium salts, then the observation of mobility in the presence of methoxide or other alkoxide ions might have been susceptible of two interpretations.

The experimental work covering the examination of routes (*b*) and (*c*) requires little comment. The compounds examined and their modes of formation are indicated in Tables II and III. Neither by alkalis, nor, so far as we were able to discover, by any other ordinary reagent, could the tertiary or quaternary bases of either the hydroxy- or the methoxy-series be converted into the desired unsaturated substances.

Route (*a*) opened with the observation that it was possible to replace the hydroxyl group in tetraethyl-β-hydroxytrimethylenediamine (which is easily prepared from diethylamine and epichlorohydrin) by chlorine, without undue polymerisation (intermolecular quaternary ammonium salt formation), by the action of phosphoryl chloride in a suitable diluent. It was impossible to eliminate hydrogen chloride from the chloro-base by treatment with either solid or dissolved alkalis, and, in particular, hot methyl-alcoholic potassium hydroxide replaced the chlorine atom by a methoxyl group; but, the chloro-base having first been methylated to give a bis-quaternary diammonium salt, this salt on treatment with alcoholic alkali did not undergo alkoxylation but passed smoothly into the unsaturated salt with elimination of hydrogen chloride (see Table I, centre column). This difference of behaviour between the tertiary and the quaternary bases is in excellent accord with the general theory of elimination reactions.

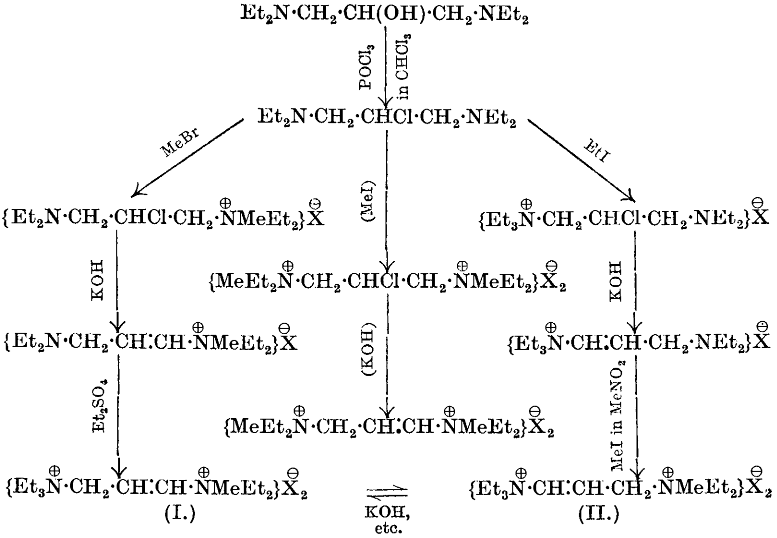
Confirmation of the structure of this salt was obtained by degradation. Reduction of the chloride in acetic acid with hydrogen and platinum-black yielded the corresponding saturated trimethylenediammonium salt, which was independently prepared for comparison from trimethylene dibromide *via* tetraethyltrimethylenediamine; and oxidation of the unsaturated salt with permanganate gave methyldiethylamine and the betaine formulated below, which also was independently prepared for comparison from ethyl chloroacetate *via* ethyl diethylaminoacetate:



$$\begin{tikzcd}
\{MeEt_2\overset{\oplus}{N}\cdot CH_2\cdot CH{:}CH\cdot\overset{\oplus}{N}MeEt_2\}\overset{\ominus}{X}_2 \arrow[r, "KMnO_4"'] \arrow[d, "H_2"', "Pt"] & MeEt_2\overset{\oplus}{N}\cdot CH_2\cdot\overset{\ominus}{C}O_2 + [\overset{\ominus}{C}O_2\cdot\overset{\oplus}{N}MeEt_2] \arrow[d] \\
\{MeEt_2\overset{\oplus}{N}\cdot CH_2\cdot CH_2\cdot CH_2\cdot\overset{\oplus}{N}MeEt_2\}\overset{\ominus}{X}_2 & \overbrace{CO_2 + NMeEt_2}
\end{tikzcd}$$

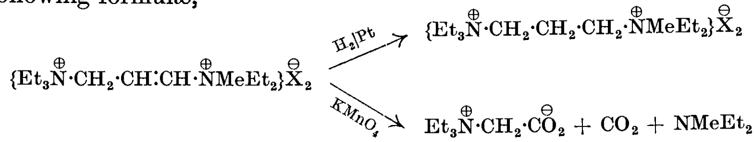
The above unsaturated salt, being symmetrically alkylated on its two nitrogen atoms, cannot be investigated with regard to its mobility, and in order to obtain a pair of isomeric salts suitable for this purpose it was necessary to effect monoalkylation of the

TABLE I.



ditertiary chloro-base with two different alkyl groups. Suitable conditions were found for the introduction of a single methyl and a single ethyl group, and the quaternary ammonium poles thus formed then determined the elimination of hydrogen chloride with the production of unsaturated salts when the tertiary-quaternary chloro-compounds were treated with methyl-alcoholic potassium hydroxide. All that now remained was to introduce the same alkyl groups in the reverse order into the tertiary-quaternary unsaturated salts (Table I, lateral columns), in order to obtain the required isomerides.

The isomeric bis-quaternary unsaturated salts (Table I, bottom) are generally similar to each other, but the picrates, which were employed for purification and identification (and, as is shown later, for separation), differ markedly in appearance and in solubility in acetone; and each increases the solubility of the other on admixture. (They melt with decomposition at the same temperature, and, as is usual with the bis-quaternary diammonium picrates encountered in this investigation, do not depress each other's m. p. on admixture; it was therefore necessary in dealing with these and other bis-quaternary salts to use solubility and mixed-solubility determinations for the purposes for which m. p.'s and mixed m. p.'s are usually employed.) In their chemical properties the two salts closely resembled their symmetrical analogue. Catalytic reduction gave the appropriate saturated diammonium salt. Oxidative fission by permanganate led in each case to the betaine corresponding to the ascribed constitution. These experiments, which are illustrated in their application to one of the isomerides by the following formulæ,



$$\begin{tikzcd}[column sep=small] & \{Et_3\overset{\oplus}{N}\cdot CH_2\cdot CH_2\cdot CH_2\cdot\overset{\oplus}{N}MeEt_2\}\overset{\ominus}{X}_2 \\ \{Et_3\overset{\oplus}{N}\cdot CH_2\cdot CH{:}CH\cdot\overset{\oplus}{N}MeEt_2\}\overset{\ominus}{X}_2 \arrow[ur, "H_2/Pt"] \arrow[dr, "KMnO_4"'] & \\ & Et_3\overset{\oplus}{N}\cdot CH_2\cdot C\overset{\ominus}{O}_2 + CO_2 + NMeEt_2 \end{tikzcd}$$

serve to confirm the deduction from the physical evidence (mixed solubility exaltation) that the salts are isomerides having separate individuality, and they also show that the isomerism is structural rather than stereochemical; finally they confirm the conclusion, derived from the synthetical evidence already cited, and supported by the theory of elimination reactions, that in the preparation of the two salts the double linking is formed (and when formed remains) on that side of the molecule whose nitrogen atom first becomes quaternary (Table I).

The salts having been synthesised and their constitutions confirmed by degradation, the way was clear to investigate their interconversion; and it was found that each underwent moderately rapid partial conversion into the other in the presence either of cold 0·1*N*-aqueous alkali hydroxide or of cold 0·1*N*-*iso*propyl-alcoholic sodium *iso*propoxide (Table I). We have not yet attempted to determine the proportion in which the isomerides are present at equilibrium, but we have isolated from mixtures obtained from either starting point some 40—48% of isomeride (II), and 10—14% of isomeride (I), the incompletely separated portions in all cases consisting mainly of compound (I).

We may add that a careful study of the action of the reagents used as catalysts in the above interconversion experiments was included in the investigation already mentioned of the possibility of forming unsaturated diammonium salts from the β-hydroxy- and β-methoxy-saturated salts formulated in Tables II and III. The results absolutely exclude the theory that interconversion is initiated by an addition of water or alcohol to the unsaturated linking, and thus confirm the view that the change is prototropic.

The results of this investigation may, then, be summarised qualitatively in the statement that the tautomerides examined, although isolable as separate individuals, undergo facile prototropic interconversion in the presence of moderate concentrations of hydroxide and alkoxide ions. The case therefore differs in the expected sense from that of the glutaconic esters, since Feist showed by ozonolysis (*Annalen*, 1922, **428**, 51, 71) that unsymmetrical esters

TABLE II.

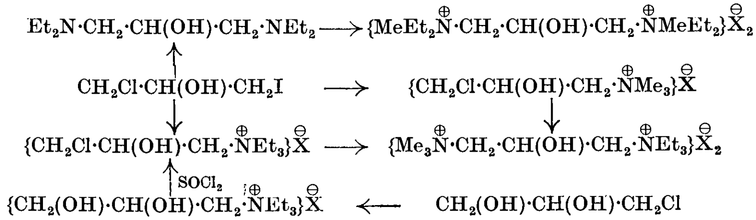
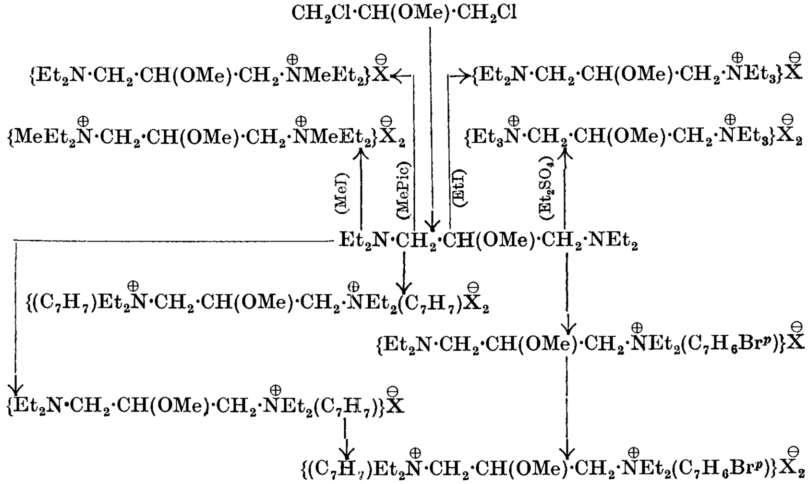


TABLE III.



of the series do not maintain their individuality as separate isomerides but pass into tautomeric mixtures. Since the theoretical significance of these results and comparisons has, as it were, been discussed in advance of the facts, this introductory statement may be concluded with a reference to Burton and Ingold's explanation (*loc. cit.*), based on the distinctive behaviour of permanent and time-variable polarisations, of why that group which attracts electrons the more powerfully gives the stronger *m*-orientation in aromatic substitution but yet was expected to be the less effective group for the induction of prototropic mobility.

EXPERIMENTAL

(A) *Derivatives of* β-*Hydroxytrimethylenediamine.*

(Formulæ in Table II.)

α-Chloro-α′-iodo*iso*propyl alcohol was prepared (compare Reboul, *Annalen, Suppl.*, I, 225, 228) by gradual addition of 66% hydriodic acid to epichlorohydrin. The product, extracted with ether after addition of water, was washed with water and aqueous sodium thiosulphate and sodium carbonate, dried, and distilled (b. p. 110°/9 mm.).

The alcohol reacts vigorously with diethylamine, yielding tetraethyl-β-hydroxytrimethylenediamine (*vide infra*), and it was not found possible to prepare diethyl-γ-chloro-β-hydroxypropylamine in this way.

The chloroiodo-alcohol (20 g.) was heated with 33% alcoholic trimethylamine (15 c.c.) in a closed tube for 12 hours at 75—80°. The *trimethyl-γ-chloro-β-hydroxy-*n*-propylammonium iodide* thus obtained separated from ether–alcohol in prisms (12 g.), m. p. 140—150° (decomp.) (Found : C, 25·3; H, 5·4. $C_6H_{15}ONClI$ requires C, 25·8; H, 5·4%).

NNN-*Trimethyl-*N′N′N′*-triethyl-β-hydroxytrimethylenediammonium picrate* was prepared by boiling the above iodide (5·0 g.) with anhydrous triethylamine (2·5 g.) for 12 hours under reflux, and converting the bis-quaternary chloride iodide (m. p. 237° decomp.) (yield 66%) into the picrate by means of aqueous sodium picrate. The salt separated from dilute alcohol in needles, m. p. 230° (Found : C, 43·3; H, 5·3. $C_{24}H_{34}O_{15}N_8$ requires C, 42·8; H, 5·0%).

Triethyl-γ-chloro-β-hydroxy-*n*-propylammonium iodide was obtained from the chloroiodo-alcohol (20 g.) by boiling with anhydrous triethylamine (8·7 g.), and converted into the picrate (m. p. 223°) with sodium picrate.

The above iodide (10 g.), when heated in a closed tube at 100° with 33% alcoholic trimethylamine (6 c.c.), yielded a salt (m. p. 237°), from which a diammonium picrate was obtained identical with that described above (Found : C, 43·0; H, 4·9%).

The reaction product (30 g.) from anhydrous triethylamine and α-chlorohydrin was heated under reflux with thionyl chloride (14 g.) and chloroform. The residue obtained on evaporation of the chloroform, when mixed with aqueous sodium picrate, yielded triethyl-γ-chloro-β-hydroxy-*n*-propylammonium picrate identical with that described above.

Tetraethyl-β-hydroxytrimethylenediamine.—This base was prepared by a modification of Reboul's method (*Compt. rend.*, 1883, **97**, 1488, 1556). A mixture of epichlorohydrin (30 c.c.) and diethylamine (100 c.c.) was kept under reflux until a brisk reaction had set in (2—3 hours) and subsided. The next day the semi-solid product was dissolved in water and acidified. After two extractions with ether to remove non-basic compounds, the solution was made alkaline and again extracted, the diamine, b. p. 114°/9 mm., being thus obtained in 82% yield. The *picrate* separated from water or 95% alcohol in prisms, m. p. 163° (Found : C, 41·7; H, 5·0. $C_{23}H_{32}O_{15}N_8$ requires C, 41·8; H, 4·9%). The benzoyl derivative prepared by the Schotten–Baumann method was a colourless oil, b. p. 185—190°/10 mm., and its picrate crystallised from water in needles, m. p. 198—200°.

NNN-*Methyldiethyl*-N′N′N′-*methyldiethyl*-β-*hydroxytrimethylenediammonium picrate* was prepared by methylation of the hydroxyditertiary base with methyl iodide and conversion of the diquaternary iodide into the picrate with aqueous sodium picrate. The salt separated from water in needles, m. p. 259—260° (decomp.) (Found : C, 43·6; H, 5·2. $C_{25}H_{36}O_{15}N_8$ requires C, 43·4; H, 5·2%).

Methyldiethyl-γ-*diethylamino*-β-*hydroxy*-n-*propylammonium picrate* was isolated as a by-product from an unsuccessful experiment in which a sample of tetraethyl-β-methoxytrimethylenediamine containing some β-hydroxy-compound (see below) was incompletely methylated with methyl iodide. The salt separated from water or acetone in prisms, m. p. 205° (decomp.) (Found : C, 42·5; H, 5·2. $C_{24}H_{34}O_{15}N_2$ requires C, 42·7; H, 5·2%).

(B) *Derivatives of* β-*Methoxytrimethylenediamine.*

(Formulæ in Table III.)

Tetraethyl-β-*methoxytrimethylenediamine.*—αγ-Dichloro-β-methoxypropane, prepared in 67% yield from α-dichlorohydrin, methyl iodide, and silver oxide, was heated with a slight excess of diethylamine in a sealed tube at 100°. After basification and extraction with ether the *methoxy-base* was obtained as an oil, b. p. 98—101°/9 mm. The same compound was also obtained by pouring tetraethyl-β-chlorotrimethylenediamine (see below) in a thin stream (30 g.) into a boiling solution of potassium hydroxide (60 g.) in methyl alcohol (60 g.), the product being extracted with ether after addition of water (Found: OMe, 12·8, 13·0. $C_{12}H_{18}ON_2$ requires OMe, 14·4%). The *picrate* separated from dilute alcohol in prisms, m. p. 110° (Found : C, 42·8; H, 5·4; OMe, 4·2. $C_{24}H_{34}O_{15}O_8$ requires C, 42·7; H, 5·0; OMe, 4·6%), and the *chloroplatinate* was obtained as a microcrystalline powder, m. p. 215° (decomp.) (Found : C, 23·2; H, 5·0. $C_{12}H_{30}ON_2Cl_6Pt$ requires C, 23·2; H, 4·9%).

Methyldiethyl-γ-*diethylamino*-β-*methoxy*-n-*propylammonium Salts.*—The methoxy-diamine (1·1 g.) was warmed on the steam-bath with a solution of 2 : 4 : 6-trinitroanisole (1·32 g.) in benzene until the liquid picrate was no longer precipitated. The salt was washed with benzene and ether, and converted into the chloride by treatment with hydrochloric acid, filtration of the picric acid, extraction with benzene, and complete evaporation of the aqueous solution. The chloride was a stiff syrup which, on addition of chloroplatinic acid, gave a *chloroplatinate*, which separated from water in bright orange prisms, m. p. 217—218° (decomp.) (Found : C, 24·4; H, 5·0. $C_{13}H_{32}ON_2Cl_6Pt$ requires C, 24·4; H, 5·0%). Treatment of the picrate with a further quantity of trinitroanisole led to the formation of the bis-quaternary compound described below.

NNN-*Methyldiethyl*-N′N′N′-*methyldiethyl*-β-*methoxytrimethylenediammonium Salts.*—The methoxy-diamine (10 g.) was boiled for 1 hour with methyl iodide (17 g.); water was then added and the reactants were removed by extraction with ether. The aqueous solution was concentrated by evaporation, treated with excess of silver oxide, filtered, acidified with hydrochloric acid, and evaporated at the ordinary temperature over potassium hydroxide in a vacuum. The diammonium chloride was thus obtained as a clear glass, which yielded a *chloroplatinate* rather sparingly soluble in water, from which it separated in prisms, m. p. 237—238° (decomp.) (Found : C, 25·4; H, 5·1; OMe, 3·4. $C_{14}H_{34}ON_2Cl_6Pt$ requires C, 25·7; H, 5·2; OMe, 4·7%). The *picrate* separated from acetone–alcohol in plates or flattened prisms, m. p. 160—161° (Found : C, 44·2; H, 5·3. $C_{26}H_{38}O_{15}N_8$ requires C, 44·4; H, 5·4%). If the methylation of the α-dichlorohydrin has been incomplete, the circumstance is readily revealed in the preparation of this, since the corresponding hydroxytrimethylene salt (above) is much less soluble in acetone and is readily separated.

When the methoxy-diamine (5 g.) was heated with methyl iodide (17 g.) in nitromethane (10 c.c.) under reflux for 2 hours, the product obtained, on treatment with a large excess of ether, yielded a syrupy iodide, which was finally obtained as a very hygroscopic solid by repeated precipitation from absolute alcohol by means of ether. From this iodide the *picrate* was obtained as an oil, which crystallised from acetone in prisms, m. p. 164—167° (Found : C, 44·4; H, 5·5; OMe, 4·1. $C_{26}H_{38}O_{15}N_8$ requires C, 44·4; H, 5·4; OMe 4·4%).

*Triethyl-γ-diethylamino-*β-*methoxy*-n-*propylammonium Salts.*—The methoxy-diamine (20 g.) was boiled under reflux for 16 hours with ethyl iodide (30 g.), and the aqueous solution of the ammonium iodide obtained by addition of water and extraction of the unchanged reactants with ether was concentrated and treated with excess of silver oxide. Addition of picric acid to the filtered solution caused the precipitation of a *picrate*, which separated from hot water in prisms, m. p. 220° (Found : C, 44·5; H, 5·5. $C_{26}H_{38}O_{15}N_8$ requires C, 44·4; H, 5·4%). The same picrate was obtained when the methoxy-diamine was treated with one equivalent of trinitrophenetole in benzene solution. The corresponding *chloroplatinate* crystallised from water in needles, m. p. 224—225° (decomp.)

(Found: C, 24·7; H, 5·2. $C_{14}H_{34}ON_2Cl_6Pt$ requires C, 25·7; H, 5·2%). The analysis suggests that the specimen of methoxy-diamine from which this salt was prepared may have contained some hydroxy-diamine (compare preceding paragraph).

NNN-*Triethyl*-N′N′N′-*triethyl*-β-*methoxytrimethylenediammonium Salts.*—The methoxy-base (2·0 g.) was heated on the steam bath in well-dried apparatus for 50 hours with ethyl sulphate (5·0 g.). The mixture, to which water was added, was then heated to boiling, and a boiling solution of barium chloride added. The filtered aqueous solution was extracted with chloroform and evaporated to dryness, and the residue was dissolved in alcohol and recovered by evaporation of the filtered solution. The syrupy chloride thus obtained yielded a *chloroplatinate*, which separated from water in orange prisms, m. p. 236° (decomp.) (Found: C, 27·5; H, 5·4. $C_{16}H_{38}ON_2Cl_6Pt$ requires C, 28·2; H, 5·6%).

Benzyldiethyl-γ-diethylamino-β-*methoxy*-n-*propylammonium Salts.*—The methoxy-diamine (5 g.) was boiled under reflux with benzyl chloride (3·2 g.) in absolute alcohol (20 c.c.). Water was added, the residual benzyl chloride extracted with ether, and the alkaline aqueous layer acidified with hydrochloric acid and evaporated. The residue thus obtained yielded a *chloroplatinate* moderately easily soluble in water, from which it crystallised in prisms, m. p. 201° (decomp.) (Found: C, 31·6; H, 5·3. $C_{19}H_{36}ON_2Cl_6Pt$ requires C, 31·8; H, 5·0%).

NNN-*Benzyldiethyl*-N′N′N′-*benzyldiethyl*-β-*methoxytrimethylenediammonium Salts.*—The methoxy-amine (5 g.) was warmed with benzyl bromide (12 g.). The white solid formed was dissolved in water, extracted with ether, and the residual syrup, obtained by evaporation of the aqueous layer to dryness, was treated with chloroplatinic acid. The *chloroplatinate* crystallised from boiling water, in which it was slightly soluble, as a pale yellow solid, m. p. 195° (decomp.) (Found: C, 38·4; H, 5·3. $C_{26}H_{42}ON_2Cl_6Pt$ requires C, 38·7; H, 5·2%). The picrate and the chloroaurate were obtained only as syrups, and the above chloroplatinate liquefied under boiling water.

p-*Bromobenzyldiethyl-γ-diethylamino*-β-*methoxy*-n-*propylammonium Salts.*—2 : 4 : 6-Trinitrophenyl *p*-bromobenzyl ether (10 g.), which has not previously been described, was prepared by the action of silver picrate on *p*-bromobenzyl bromide and crystallised from alcohol (prisms, m. p. 125°), and was added in small portions to the methoxy-diamine (5 g.) dissolved in benzene (100 c.c.). The reaction was completed by warming on the steam-bath over-night, and the liquid picrate was separated, washed with benzene, and converted into the chloride by the addition of hydrochloric acid, removal of picric acid by filtration and extraction with benzene, and evaporation of the solution. The residue yielded a *chloroplatinate*; this was very slightly soluble in boiling water, under which (as with the other benzyl derivatives of this series) it liquefied, and crystallised from water in prisms, m. p. 210° (decomp.) (Found : C, 29·0; H, 4·5. $C_{19}H_{35}ON_2Cl_6BrPt$ requires C, 28·7; H, 4·4%).

NNN-p-*Bromobenzyldiethyl*-N′N′N′-*benzyldiethyl*-β-*methoxytrimethylenediammonium Salts*.—The preceding chloride was converted by silver oxide into the hydroxide, and this was warmed at 45° with excess of benzyl iodide for 48 hours. The excess of benzyl iodide was removed with ether, and the ammonium salt in the aqueous layer was converted into the hydroxide and thence into the chloride. On treatment with chloroplatinic acid, a *chloroplatinate*, insoluble in the usual solvents, m. p. 156—160° (decomp.), was obtained (Found : C, 35·5; H, 4·3. $C_{26}H_{41}ON_2Cl_6BrPt$ requires C, 35·3; H, 4·6%). The same compound was obtained by the action of *p*-bromobenzyl bromide in alcoholic solution on benzyldiethyl-γ-diethylamino-β-methoxy-*n*-propylammonium hydroxide.

(C) *Derivatives of* β-*Chlorotrimethylenediamine.*

(Formulæ in Table I.)

Tetraethyl-β-*chlorotrimethylenediamine*.—A solution of phosphorus oxychloride (25 c.c.) in chloroform (25 c.c.) was added to a solution of tetraethyl-β-hydroxytrimethylenediamine (50 g.) in the same solvent (50 c.c.) as rapidly as the vigorous reaction would allow. The product was heated for 10 minutes under reflux, cooled, and poured into water. After removal of the chloroform by distillation from a steam-bath, the aqueous residue was basified and extracted with ether whilst still slightly warm (to avoid crystallisation of sodium phosphate). The chloro-amine had b. p. 109°/10 mm. (yield 40 g.), and its *picrate* crystallised from dilute alcohol in prisms, m. p. 153° (Found: C, 40·7; H, 4·7; Cl, 5·1. $C_{23}H_{31}O_{14}N_8Cl$ requires C, 40·7; H, 4·6; Cl, 5·2). Attempts were made to eliminate hydrogen chloride from this base both by dissolved and by solid alkalis, and by distillation of the hydroxide solutions obtained by the action of silver oxide and water on the product of the action of the chloro-base on itself (in nitromethane) and on trimethylamine. When unchanged chloro-base was not recovered, deep-seated decomposition occurred, the only definitely recognised product being diethylamine. The only exception to this statement is that in an experiment in which the chloro-base was distilled with soda-lime a small amount of tetraethyl-β-hydroxytrimethylenediamine was obtained.

NNN-*Methyldiethyl*-N′N′N′-*methyldiethyl*-β-*chlorotrimethylenediammonium Salts.*—The above chloro-base (10 g.) and methyl iodide (15 c.c.) were mixed under an efficient reflux condenser. The mixture at once became turbid and shortly afterwards boiled and a syrup separated which solidified as the mixture cooled. It was dissolved in water, extracted with ether to remove non-saline impurities, and the aqueous solution was evaporated to dryness. The crystalline iodide thus obtained yielded a *picrate*, which separated from 80% alcohol in plates, m. p. 215° (decomp.) (Found: C, 42·6; H, 5·3. $C_{25}H_{35}O_{14}N_8Cl$ requires C, 42·5; H, 5·0%). The corresponding bromide was formed by the action of methyl bromide in nitromethane on the ditertiary chloro-base; it was a colourless solid moderately easily soluble in methyl alcohol, and with sodium picrate solution gave the above picrate.

Methyldiethyl-β-*chloro*-γ-*diethylamino*-n-*propylammonium Salts.*—The ditertiary chloro-base (10 g.) was shaken for 15 minutes with methyl iodide (25 c.c.), and the whole product immediately dissolved in alcohol and treated with 500 c.c. of ether. An iodide which separated as a yellow solid having an alkaline reaction yielded with sodium picrate and picric acid a *dipicrate*, which crystallised from dilute alcohol in needles, m. p. 133° (Found: C, 41·7; H, 4·9. $C_{24}H_{33}O_{14}N_8Cl$ requires C, 41·6; H, 4·8%). The corresponding bromide, which was found a more convenient intermediate for the preparation of unsaturated salts, was prepared directly from the ditertiary chloro-base (20 g.), methyl bromide (18 c.c.), and nitromethane (18 c.c.). The mixture was kept over-night, dissolved in water, and extracted with ether, and the aqueous solution neutralised with hydrochloric acid and evaporated to dryness, desiccation being completed in a vacuum over sulphuric acid.

Triethyl-β-*chloro*-γ-*diethylamino*-n-*propylammonium Salts.*—A mixture of the ditertiary chloro-base (20 g.), ethyl iodide (14 g.), and nitromethane (20 c.c.) was kept for 3 days, filtered from a small amount of by-product (m. p. 213—214°, decomp. Found: C, 42·1; H, 8·0; N, 8·7; I, by titration, 41·2. Corresponding picrate, m. p. 184°, C, 50·1; H, 6·9%), mixed with water, and extracted with ether. The alkaline aqueous extract was neutralised with hydrochloric acid and evaporated to dryness, the desiccation being completed over sulphuric acid in a vacuum.

(D) *Formation of* αγ-*Propenylenediammonium Salts.*

(Formulæ in Table I.)

NNN-*Methyldiethyl*-N′N′N′-*methyldiethyl*-αγ-*propenylenediammonium Salts.*—The corresponding β-chlorotrimethylenediammonium bromide (38 g.), dissolved in ethyl alcohol (250 c.c.), was heated under reflux for 30 minutes with a solution of " A.R." potassium hydroxide (5·7 g.) in ethyl alcohol (50 c.c.). The slightly alkaline liquid was acidified with hydrochloric acid, filtered, and evaporated to dryness, and the residue was treated with excess of sodium picrate solution. The unsaturated *picrate* (yield, 19 g.) usually contained a little of the tertiary-quaternary salt formed by the loss of methyl from one of the nitrogen atoms during the above alkali treatment, but this was readily removed by extracting the more soluble di-quaternary salt with acetone and precipitating it with alcohol. The pure salt separated from acetone–alcohol in prisms, m. p. 234° (decomp.) (Found : C, 44·8; H, 5·2. $C_{25}H_{34}O_{14}N_8$ requires C, 44·8; H, 5·1%).

Methyldiethyl-γ-diethylamino-Δ^{α}-propenyl-α-ammonium Salts.—The appropriate tertiary-quaternary β-chlorotrimethylene salt (chloride-bromide, 24·7 g.), dissolved in ethyl alcohol (100 c.c.), was heated under reflux for 20 minutes with a solution of potassium hydroxide (10 g.) in the same solvent (100 c.c.). The *picrate* (yield, 23·5 g. after two crystallisations), isolated as described in the preceding paragraph, crystallised from acetone in prisms, m. p. 198° (Found : C, 44·2; H, 4·9. $C_{24}H_{32}O_{14}N_8$ requires C, 43·9; H, 4·9%). Cold moist silver oxide had no action on the hydroxide of the base and the original salt was recovered unchanged.

$N^{\alpha}N^{\alpha}N^{\alpha}$-*Methyldiethyl*-$N^{\gamma}N^{\gamma}N^{\gamma}$-*triethyl-$\Delta^{\alpha}$-propenylene-αγ-diammonium Salts.*—The preceding tertiary-quaternary picrate was dissolved in a small excess of dilute hydrochloric acid and the picric acid was removed by filtration and subsequent extraction with benzene. The chloride solution thus obtained was mixed with excess of sodium carbonate and evaporated to dryness, and the residue was extracted with nitromethane. The filtered extract was treated at intervals of 4 hours with two successive portions of ethyl sulphate (4 g. each) and anhydrous sodium carbonate (2 g. each) and with one of ethyl sulphate (5 g.), the mixture being heated throughout and for a further 16 hours on the steam-bath with precautions against access of atmospheric moisture. Water was then added and the aqueous solution, after being washed with ether, was evaporated to dryness. The residue on treatment with aqueous sodium picrate yielded the unsaturated diquaternary *picrate* (12 g. after two crystallisations), which separated from acetone in groups of stout plates, m. p. 229—230° (decomp.) (Found : C, 45·8; H, 5·2. $C_{26}H_{36}O_{14}N_8$ requires C, 45·6; H, 5·3%).

Triethyl-γ-diethylamino-Δ^{α}-propenyl-α-ammonium Salts.—The appropriate saturated chloro-salt (chloride-iodide, 27 g.), dissolved in ethyl alcohol (100 c.c.), was heated for 20 minutes under reflux with a solution of potassium hydroxide (8·0 g.) in ethyl alcohol (80 c.c.). The product was acidified with concentrated hydrochloric acid, filtered, and evaporated completely to dryness. The residue on treatment with aqueous sodium picrate yielded a syrupy picrate, which on solution in acetone and precipitation by alcohol gave the crystalline tertiary-quaternary *dipicrate*, together with some syrupy residues the nature of which was not elucidated. The crystalline picrate separated from acetone–alcohol in needles, m. p. 167—168° (yield, 17 g. after two crystallisations) (Found : C, 44·4; H, 5·3. $C_{25}H_{34}O_{14}N_8$ requires C, 44·8; H, 5·1%).

N$^{\alpha}$N$^{\alpha}$N$^{\alpha}$-*Triethyl*-N$^{\gamma}$N$^{\gamma}$N$^{\gamma}$-*methyldiethyl*-Δ^{α}-*propenylene*-$\alpha\gamma$-*diammonium Salts*.—The preceding picrate was converted into the aminoammonium chloride by treatment with sodium carbonate as described in the case of the isomeride. The nitromethane solution of the base-salt was boiled under reflux with methyl iodide for 24 hours and treated with water. The aqueous extract was washed with ether and evaporated to dryness, and the residue was converted into the *picrate*, which crystallised from acetone in feathery clusters of slender needles, m. p. 230° (decomp.) (Found : C, 45·7; H, 5·4. $C_{26}H_{36}O_{14}N_8$ requires C, 45·6; H, 5·3%). This salt and the isomeride described above have the same m. p. and there is no depression on admixture; they are nevertheless distinct individuals as is proved by (*a*) their mixed-solubility exaltation (Section G), (*b*) their oxidative fission (Section F). Moreover, they are instantly distinguishable by their characteristic and very different crystalline forms, and as each crystallises in its own form even when mixed with the isomeride the presence of one as an impurity in the other can usually be detected visually.

(E) *Reduction of* $\alpha\gamma$-*Propenylenediammonium Salts.*

Reduction of NNN-*Methyldiethyl*-N′N′N′-*methyldiethyl*-$\alpha\gamma$-*propenylenediammonium Salts to Corresponding Trimethylenediammonium Salts*.—The unsaturated picrate (7 g.) was dissolved in hydrochloric acid, and, after removal of the picric acid with benzene, the aqueous solution was completely evaporated. The residue, dissolved in a small amount of glacial acetic acid, was shaken with platinum-black (1 g.) in hydrogen (1 atm.) for 5·5 hours, during which 245 c.c. of the gas were absorbed (= 2·00 atoms). The filtered solution was evaporated to dryness and the *picrate*, prepared from the residue by means of aqueous sodium picrate, was crystallised twice from acetone and obtained as needles, m. p. 282° (decomp.) (Found : C, 44·6; H, 5·6. $C_{25}H_{36}O_{14}N_8$ requires C, 44·6; H, 5·4%).

Independent Preparation of NNN-*Methyldiethyl*-N′N′N′-*methyldiethyltrimethylenediammonium Salts*.—Trimethylene dibromide (1 mol.) was condensed with diethylamine (2 mols.) in nitromethane and the product was treated with water and alkali and extracted with ether. The tetraethyltrimethylenediamine, which after rectification had b. p. 81·9°/9 mm., was treated with excess of methyl iodide in nitromethane. Heat was evolved and part of the diquaternary iodide crystallised; the remainder was precipitated with ether. The picrate (Found : C, 44·4; H, 5·4%) obtained from this iodide was compared with that prepared by reduction, and since the absence of a mixed m. p. depression is not evidence of identity when as in this case melting is attended with decomposition, we determined the individual and mixed solubilities in acetone (see Section G) and showed that there was no mixed-solubility exaltation. The solubility of the salt at 30·3° in " A.R." acetone is 0·0087 g./c.c. As a check on the utility of this test the salt was similarly compared with its higher homologue *NNN*-methyldiethyl-*N'N'N'*-triethyltrimethylenediammonium picrate (see below). The solubility of this salt is 0·0126 g./c.c., and a mixture of the two salts had the solubility 0·0156 g./c.c.

Reduction of $N^{\alpha}N^{\alpha}N^{\alpha}$*-Methyldiethyl-*$N^{\gamma}N^{\gamma}N^{\gamma}$*-triethyl-*$\Delta^{\alpha}$*-propenylene-αγ-diammonium Salts to Corresponding Trimethylenediammonium Salts.*—This reduction was carried out like that described at the commencement of this Section. The saturated *picrate* separated from acetone in rhombs, m. p. 263—264° (decomp.) (Found : C, 45·5; H, 5·8. $C_{26}H_{38}O_{14}N_8$ requires C, 45·5; H, 5·5%) (solubility above).

(F) *Oxidation of αγ-Propenylenediammonium Salts.*

Oxidation of NNN*-Methyldiethyl-*N'N'N'*-methyldiethyl-αγ-propenylenediammonium Salts.*—A solution of the chloride in hydrochloric acid, prepared in the usual manner from the picrate (10 g.), was neutralised with sodium hydrogen carbonate, and treated gradually at the boiling point with 650 c.c. of a 1% solution of potassium permanganate, sodium hydrogen carbonate being added from time to time to maintain the solution as nearly neutral as possible. The faintly acid solution was filtered and evaporated, the residue extracted with alcohol, and the filtered alcoholic solution again evaporated. The residue on treatment with aqueous sodium picrate yielded *methyldiethylammonium picrate*, which separated from water in prisms, m. p. 185° (Found : C, 42·0; H, 4·9; N, 17·9. $C_{11}H_{16}O_7N_4$ requires C, 41·8; H, 5·1; N, 17·7%). The same picrate was prepared from methyldiethylamine for comparison (Found : C, 42·1; H, 5·2%).

A neutral solution of the unsaturated chloride (prepared from 10 g. of picrate) was treated with sodium carbonate (2 g.), cooled to 0°, and mechanically stirred while a solution of sodium permanganate (8 g.) in water (100 c.c.) was slowly added. Decolorisation was immediate and an odour of acetaldehyde was developed by the solution. The filtered liquid was neutralised with hydrochloric acid and a portion was tested for aldehydes by distilling its lighter fraction into a hydrochloric acid solution of 2 : 4-dinitrophenylhydrazine. The acetaldehyde-2 : 4-dinitrophenylhydrazone which separated was identified by comparison and mixed m. p. The bulk of the filtered liquid was evaporated to dryness, and the residue taken up in dilute acid. On basification an odour of methyldiethylamine (see above) was developed, and the liquid was extracted with ether to remove organic substances other than quaternary salts. The solution was again neutralised and completely evaporated and the residue was extracted with absolute alcohol, the residue obtained by evaporation of the filtered extract being again extracted with a smaller amount of the same solvent. Treatment of the residue obtained on evaporation of the second extract with saturated sodium picrate solution yielded a sparingly soluble picrate, which was identified as the original picrate by its m. p., by analysis (Found : C, 44·7 ; H, 5·1%), and by its solubility and mixed solubility with the original specimen (0·182 g./c.c. in " A.R." acetone at 30·3°). The filtrate from the precipitated picrate was acidified with excess of hydrochloric acid and the picric acid was extracted with benzene. The aqueous solution was completely evaporated, the residue extracted with absolute alcohol, and the filtered extract again evaporated. The syrupy chloride thus obtained yielded a picrate, which separated from water in plate-like aggregates of needles, m. p. 146°, and was identified as carboxymethylmethyldiethylammonium picrate (Found : C, 41·5 ; H, 4·8. Calc. : C, 41·7 ; H, 4·8%). Willstätter records (*Ber.*, 1902, **35**, 608) m. p. 153—154° for this picrate, and it was therefore prepared by his method (Found : C, 41·6 ; H, 4·9%) ; but our preparation had m. p. 146° and this m. p. was not depressed by admixture with the sample obtained by oxidation.

Oxidation of $N^{\alpha}N^{\alpha}N^{\alpha}$-*Methyldiethyl*-$N^{\gamma}N^{\gamma}N^{\gamma}$-*triethyl*-$\Delta^{\alpha}$-*propenylene-αγ-diammonium Salts.*—The picrate (4 g.) was converted into a neutral solution of the chloride, which was mixed with sodium carbonate (2 g.) and a solution of sodium permanganate (6 g.) in water (100 c.c.) Decolorisation was somewhat slower than in the preceding experiment, but faster than in the oxidation of the isomeride described below. An odour of aldehyde developed and after being kept at 30° for 1 hour the solution was filtered and worked up for quaternary ammonium picrates as before. Two picrate fractions were obtained. The less soluble (small amount) had m. p. 182—184° and appeared from its analysis to be a mixture of the unchanged unsaturated salt and the betaine salt described below. The more soluble separated from water in prisms, m. p. 193—194°, and was identified by analysis (Found: C, 43·3; H, 5·2. $C_{14}H_{10}O_9N_4$ requires C, 43·3; H, 5·2%) and comparison with the specimen prepared as described below.

Carboxymethyltriethylammonium Picrate.—Ethyl diethylaminoacetate (3 g.) was boiled under reflux with ethyl iodide (6 g.) and nitromethane (10 c.c.) for 12 hours, the product was mixed with water and extracted with ether, and the aqueous solution was evaporated to a small bulk. The residual solution was mixed with an excess of silver oxide, filtered after 1 hour, strongly acidified with hydrochloric acid, and evaporated to dryness. The betaine hydrochloride thus obtained as a colourless solid was purified by solution in alcohol and precipitation with ether and then converted into the *picrate* with sodium picrate (Found : C, 43·2; H, 5·3%).

Oxidation of $N^{\alpha}N^{\alpha}N^{\alpha}$*-Triethyl-*$N^{\gamma}N^{\gamma}N^{\gamma}$*-methyldiethyl-*$\Delta^{\alpha}$*-propenylene-αγ-diammonium Salts.*—A neutral solution of the chloride (prepared from 3·7 g. of picrate) was treated at 30° for 2·5 hours with sodium carbonate (2 g.) and a solution of sodium permanganate (6 g.) in water (100 c.c.). The residue was worked up as in the preceding cases for the soluble quaternary ammonium picrate, and this was identified as carboxymethylmethyldiethylammonium picrate by direct comparison (see above), mixed m. p. and analysis (Found : C, 41·8; H, 4·8. Calc. : C, 41·7; H, 4·8%).

Note.—Evidence of the possible mode of formation of acetaldehyde in some of these oxidations is contained in the observation that both methyldiethylamine and triethylamine are oxidised with the formation of acetaldehyde by permanganate under the conditions used.

(G) *Reversible Interconversion of* $N^{\alpha}N^{\alpha}N^{\alpha}$*-Methyldiethyl-*$N^{\gamma}N^{\gamma}N^{\gamma}$*-triethyl-*$\Delta^{\alpha}$*-propenylene-αγ-diammonium Salts and* $N^{\alpha}N^{\alpha}N^{\alpha}$*-Triethyl-*$N^{\gamma}N^{\gamma}N^{\gamma}$*-methyldiethyl-*$\Delta^{\alpha}$*-propenylene-αγ-diammonium Salts in the Presence of Alkalis.*

Identity and Purity Criteria.—Since with these salts m. p.'s and mixed m. p.'s are no guide to identity or purity, solubility and mixed-solubility determinations were used, the solvent throughout being the same sample of purchased "A.R." acetone, and the thermostat temperature 30·3°. The crude batches of the two salts (picrates) which were prepared for these experiments were first crystallised from acetone until each had developed its characteristic crystalline form, and then the crystallisation was continued under control by solubility determinations until the solubilities remained constant. These solubilities were as follows :

(I.) $\{Et_3N\cdot CH_2\cdot CH{:}CH\cdot NMeEt_2\}^{\cdot\cdot}Pic'_2$, stout plates, 0·0194 g./c.c.
(II.) $\{Et_3N\cdot CH{:}CH\cdot CH_2\cdot NMeEt_2\}^{\cdot\cdot}Pic'_2$, slender needles, 0·0072 g./c.c.

Mixtures of (I) and (II) had solubilities of upwards of 0·0300 g./c.c., *i.e.*, more than the sum of the separate solubilities.

Interconversion with 0·1N-*Sodium* iso*Propoxide.*—The picrate (I) (2·5 g.) was converted in the usual way into the chloride, which was dissolved in *iso*propyl alcohol and treated with sodium *iso*propoxide solution made from 0·23 g. of sodium, the volume being adjusted to 100 c.c. After being kept over-night at 30°, the solution was acidified with hydrochloric acid and evaporated and the chlorides were reconverted into picrates. These were fractionally crystallised from acetone, the process being controlled in the first instance by the differing appearance of the two salts, and for the terminal fractions in the later stages by solubility determinations, final confirmation of identity being obtained by mixed solubility with the original specimens. The results of the separation were :—salt (I) 0·3 g., salt (II) 1·0 g., unseparated fractions 1·2 g. The picrate (II) (2·5 g.) was treated in precisely the same way, and the yields on separation were : salt (I) 0·35 g., salt (II) 1·2 g., unseparated fractions 0·9 g.

Interconversion with 0·1N-*Aqueous Alkali.*—The picrate (I) (2·5 g.) was converted into the chloride and this was kept over-night at 30° in a 0·1*N*-solution of potassium hydroxide. The product, isolated as picrate, was not separated but was shown qualitatively to contain both isomerides by the fact that its saturated solution in acetone was saturated with respect to each isomeride. The picrate (II) was treated similarly except that the temperature was 20° and the alkali was introduced by adding silver oxide to a solution of the chloride. The product was tested in the same way with the same results.

Stability of the β-*Hydroxy- and* β-*Methoxy-bis-quaternary Salts.*—A number of these salts [see Sections (A) and (B)] were tested, and were found to be wholly or largely unaffected on treatment with aqueous hydroxide or *iso*propyl-alcoholic *iso*propoxide under the conditions of the above interconversions. Prolonged treatment, or the use of high temperatures, caused some decomposition, but careful search did not reveal the presence in the recovered materials of even small quantities of the unsaturated salts.

We wish gratefully to acknowledge that this work has been assisted by grants from the Chemical Society and from Imperial Chemical Industries Limited.

THE UNIVERSITY OF LEEDS.
UNIVERSITY COLLEGE, LONDON.
[*Received, May* 11*th*, 1931.]